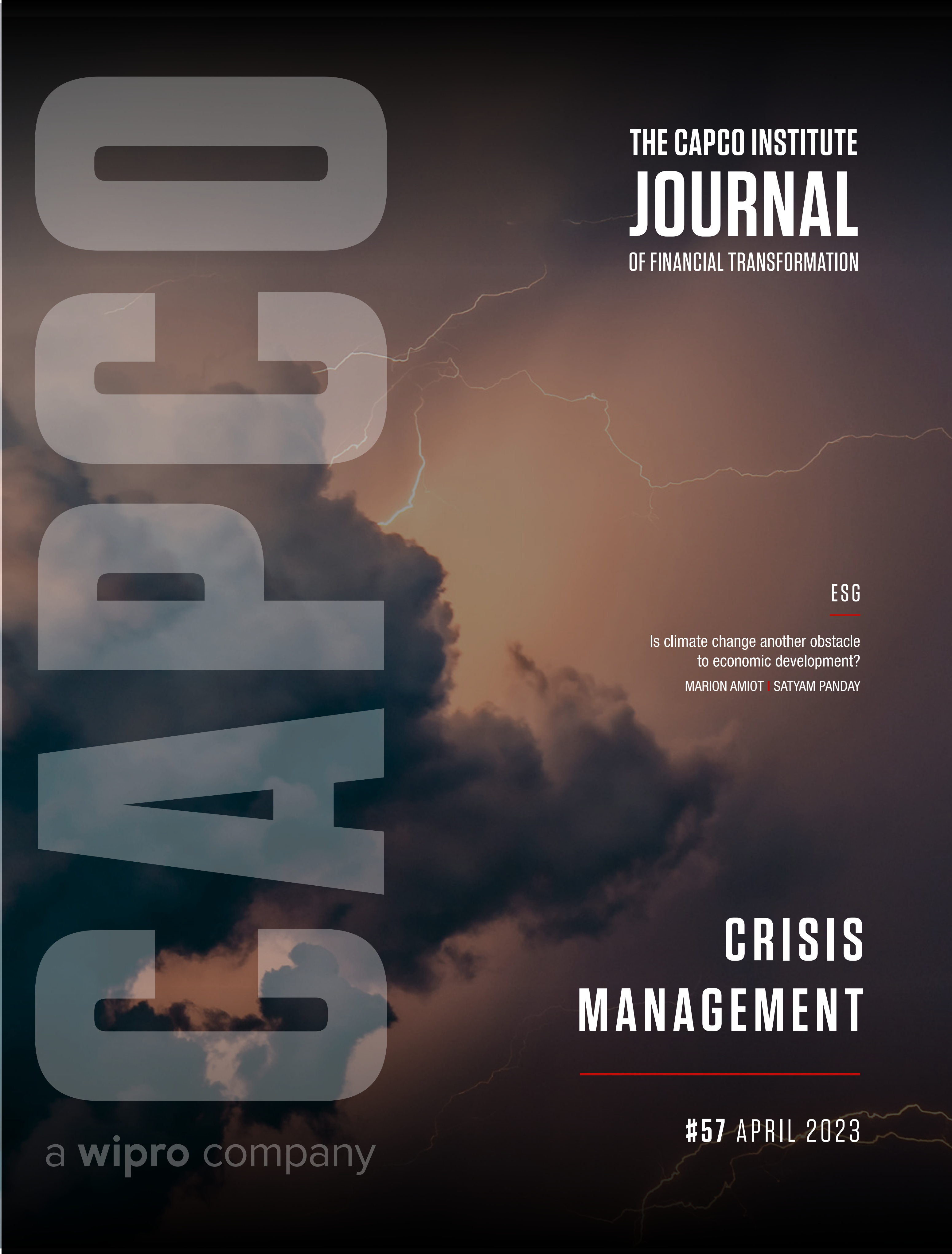

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ESG

Is climate change another obstacle to economic development?

MARION AMIOT | SATYAM PANDAY

CRISIS MANAGEMENT

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DEAR READER,

Recent events in the U.S. banking sector, and broader concerns around instability and contagion within the global financial services industry, have meant that crisis management is once more front of mind for many institutions.

In addition, the world of business and finance is facing broader geopolitical and socioeconomic challenges, ranging from conflict, climate change, inflationary pressures, and precarious energy resources. Factor in heightened regulatory and competitive pressures, and it becomes clear that financial institutions must prioritize risk management, within their own organizations and with their counterparties.

The papers in this edition of the Journal address the theme of crisis management through various lenses, including regulatory compliance and traditional risk management, as well ESG, the low carbon economy, and sustainable finance. Our authors also explore topics such as the impact of social change on the world of finance, the rise of artificial intelligence and virtual reality technologies, and cybersecurity.

Contributions in this edition come from a range of world-class experts across industry and academia, and showcase some of the very best expertise, independent thinking, and strategic insights within the financial services sector.

As ever, I hope that you find the latest edition of the Capco Journal to be engaging and informative. Thank you to all our contributors, and thank you for reading.

Lance Levy, **Capco CEO**

IS CLIMATE CHANGE ANOTHER OBSTACLE TO ECONOMIC DEVELOPMENT?[1]

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SATYAM PANDAY | Chief Emerging Market Economist, S&P Global Ratings

ABSTRACT

Over the next decades, rising temperatures will be a bigger hurdle for emerging markets and developing economies than for advanced economies. Our analysis of data from 190 countries shows that a one-time, 1-degree Celsius annual average temperature increase is more damaging for emerging markets and developing economies (EMDEs) than advanced economies (AEs). We find that seven years after such a rise, gross domestic product per capita is 0.6-0.7 percentage points lower in countries with current annual temperatures averaging 22°C-24°C (mainly EMDEs) than in those averaging 15°C (AEs) – all other things being equal. Further, we find permanent income losses arising through lower productivity and investment, with the agricultural sector taking a long-term hit. Where annual temperatures average 24°C, GDP per capita of countries least ready to cope with climate change remains 2 percentage points lower, while countries most ready see no sustained losses, seven years after the 1°C temperature shock. Economies have adapted somewhat to one-off temperature increases over the past decades, with the sensitivity of GDP to temperature shocks decreasing by about 30 percent over the past 20 years. Supportive macro policy responses have also helped economies recover from climate-related shocks, restrictive monetary policy seems to amplify the shock, whereas low real interest rates are associated with little scarring.

1. INTRODUCTION

Over the next decades, we think rising temperatures will be a bigger hurdle for emerging markets and developing economies than for advanced economies. Emerging markets and developing economies (EMDEs) contribute less than 14 percent of global greenhouse gas emissions but are among the most exposed to, and least ready to cope with, the effects of climate change. Recent extreme weather events serve as a reminder that climate change is intensifying. In a recent study, S&P Global estimates that, even if all countries meet their current climate policy pledges, low- and middle-income nations could face losses equivalent to 12 percent of GDP by 2050, compared with 3 percent for high- and upper-middle income countries [Munday et al. (2022)]. That study also suggests that as much as 4 percent of global GDP annually can be at risk from climate change by 2050, absent adaptation measures. By comparison, during COVID-19 lockdowns in 2020, global GDP dropped 3.3 percent.

To assess whether the most vulnerable countries can cope with, and recover from, hotter temperatures, S&P Global Ratings examined the impact of physical risks on economic growth. Using data for 190 countries over roughly six decades (1965-2020), we looked at the relationship between temperature variations and distribution of real GDP per capita.

The results of our analysis show that, after a one-time 1-degree C rise in average annual temperature, GDP per capita tends to recover within two years for EMDEs (mean temperature = 22°C), while there is close to no negative impacts for advanced economies (AEs) (mean temperature = 15°C). Moreover, where the regular temperature averages

[1] This article does not constitute a rating action. All figures in this article are copyright © of Standard & Poor's Financial Services LLC. All rights reserved.

22°C-24°C, GDP per capita does not return to its previous trend level and continues to lag that of 15°C economies even after seven years.

Since lower middle-income and low-income EMDEs are concentrated in areas with much warmer climates, our results suggest that temperature rise would be another dimension holding back this set of countries to achieve durable growth in the long term – which is a precondition for convergence with high-income economies (as implied by neoclassical growth theory), although causal interpretation is difficult.

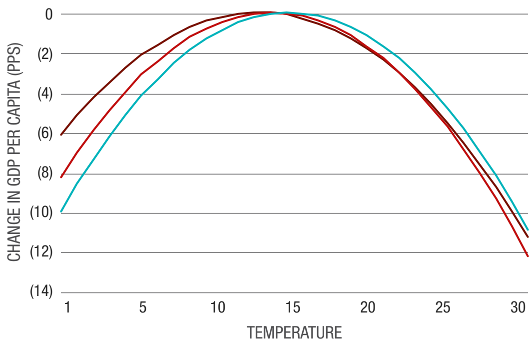
Looking under the hood of temperature shocks also shows that economic development and adaptation – both crucial for resilience to climate change – are two sides of the same coin. More developed economies with a bigger share of services activity in output and more flexible institutional set-ups do better at withstanding temperature increases. At the same time, more granular measures are needed to assess countries' readiness uncorrelated from economic development.

With the cost of physical climate risks increasing each year, the loss and damage debate also took center stage at the COP27 climate change conference in Egypt.[2] Our research highlights investing in adaptation to climate change could support long-term income prospects for EMDEs. Developing countries are calling on richer nations to help finance loss and damage linked to climate change and making their economies more resilient to cope with acute physical risks, like storms, wildfires, and drought.

2. TEMPERATURE STARTING POINTS MATTER: CLOSER TO 14°C IS MORE OPTIMAL

By linking economic output (GDP) to countries' annual average temperatures, we see that many advanced economies have more favorable temperature starting points when it comes to climate change. Using fixed-effects panel regression models (less prone to omitted variable bias as they control for unobserved time-invariant group heterogeneity, including, for example, differences in institutions) with data ranging from 1965 to 2020, we find that countries with more temperate climates tend to exhibit higher GDP per capita increases than those with harsher climates (very low or very high temperature averages), with the turning point likely to be around 13°C-15°C (Figure 1). This nonlinear relationship between annual temperature and growth is similar to findings uncovered in other studies [Burke et al. (2015), Kalkuhl and Wenz (2020)].

Figure 1: GDP responds to temperature shocks in a non-linear way



— Low range — Panel model with regional time and country fixed effect — High range

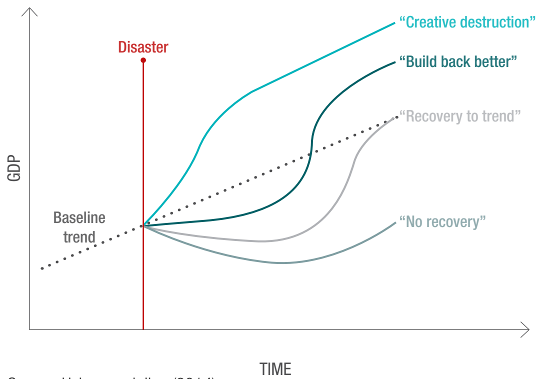
Change in GDP per capita associated with a 1°C increase in temperature (first year)

Note: The results describe the relationship between GDP per capita and temperature using a panel model estimation with country fixed effects and regional time fixed effects; the range refers to results of other modeling specifications

Pps = Percentage points

Sources: Authors' calculations; S&P Global Ratings

Figure 2: Stylized GDP outcomes: there is more than one potential outcome to economic shocks

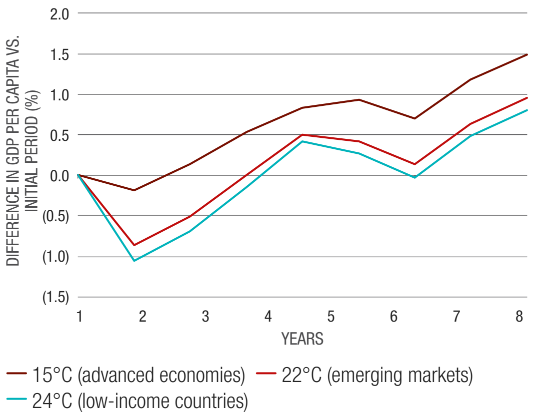


Source: Hsiang and Jina (2014)

The annual average temperature in advanced economies – such as the E.U., U.S., and Japan – is close to the optimum, at 15°C, while in EMDEs it is higher, between 19°C-24°C, suggesting that additional warming is likely to hurt EMDEs more than their richer peers. The results of our analysis show that a 1°C temperature increase would be associated with a GDP per capita drop of about 0.9 percentage points for countries where temperatures average 22°C, and 1.2 points where the average is 24°C. By comparison, there is close to no impact for economies where the average temperature is 15°C.

[2] https://bit.ly/3ZxHdye

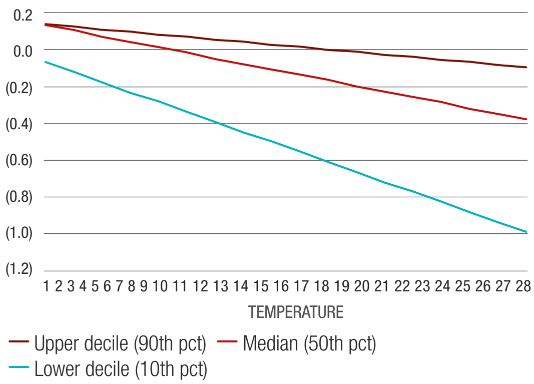
Figure 3: Temperature shocks have a permanent impact on relative GDP levels



GDP per capita response to a 1°C annual average temperature rise

Note: The results describe the relationship of the variable shown with average annual temperature using a panel model estimation with country fixed effects and regional time fixed effects. We derive impulse response functions using local projections and controlling for lags and forwards of the temperature
Sources: Authors' calculations; S&P Global Ratings

Figure 4: Output growth-at-risk exercise highlights 1°C increase in temperature is likely to make GDP contractions worse in hotter climates



GDP per capita response to a 1°C annual average temperature rise

Note: The results describe the relationship of the variable shown with average annual temperature using a panel model estimation with country fixed effects and regional time fixed effects. We derive impulse response functions using local projections and controlling for lags and forwards of the temperature
Sources: Authors' calculations; S&P Global Ratings

Although our results may be influenced by structural differences among the economies in our dataset, and important within-country variations may be hidden, they are similar to the findings of a comparable study utilizing regional and seasonal variations focused on the U.S. Increases in temperature beyond the summer average (that is, unusually warm weather) are associated with lower growth of the gross state product (gross value added during production by labor and capital at the U.S. state level) [Colacito et al. (2019)]. Furthermore, that study found the effect to be most significant in the summer months and for states where average temperatures are higher, irrespective of state income level. This further supports our finding that the starting point in temperature matters and that there is a nonlinear relationship between temperature and growth.

2.1 Four potential exit paths after a climate shock

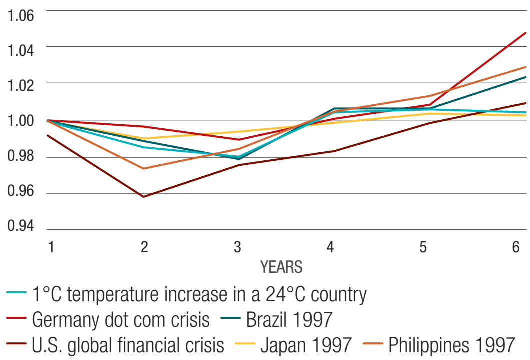
One way to look at the macroeconomic ramifications of climate change for vulnerable countries is to consider the impact on growth after temperature fluctuations and weather extremes. We focus on whether temperature increases reduce growth permanently or temporarily. There are four potential hypotheses of generalized economic outcomes in subsequent years, as illustrated by Hsiang and Jina (2014) (Figure 2). The temperature/climate shock triggers:

- A period of accelerated growth (a positive shock) after which growth returns to the baseline rate but at a higher level (creative destruction).
- Slow growth or a contraction, then a quick catch-up, and eventually convergence to a trajectory that is above the initial baseline growth rate and initial potential GDP level (build back better).
- A downturn, then a return to the previous growth path and potential GDP trajectory (recovery to trend).
- Contraction and slower growth for a finite interval before a resumption of the original growth rate, but without a period of acceleration and no return to the original baseline GDP trend.

2.2 Income losses can be permanent even if growth recovers

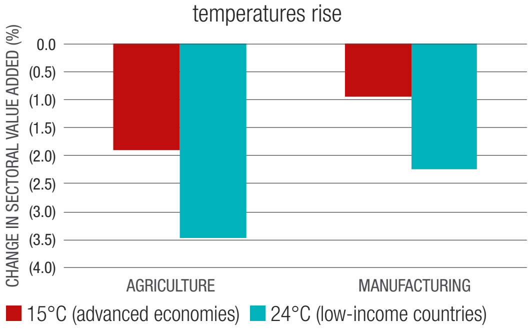
Our results show that even though a one-time temperature increase has a temporary impact on economic growth, there is a permanent relative loss of GDP in countries with hotter climates than those with lower average temperatures. GDP per capita tends to recover to the previous peak within two years after the shock, at the latest, for countries where the annual average temperature is about 22°C-24°C, namely lower-income countries and emerging markets (Figure 3). However, GDP per capita for such countries does not return to its previous trend or catch up to that of economies with cooler climates (average of 15°C); a GDP per capita gap of 0.6-0.7 points remains seven years after a one-time 1°C temperature increase. This suggests that economies with warmer climates are more likely to follow the "no recovery" path, meaning

Figure 5: External temperature shocks are slightly milder than shocks related to structural issues



Change in GDP per capita, constant local currency (period 1 = 1)
Sources: National Statistical Institutes, S&P Global Ratings

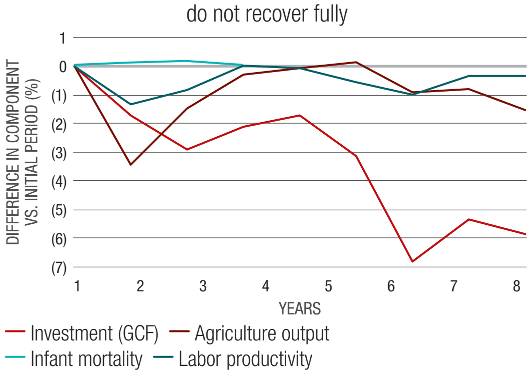
Figure 6: Agriculture is the sector most affected when temperatures rise



Impact of a 1°C annual average temperature rise on sectoral value added in the first year.

Note: The results describe the relationship of sectoral value added for a one degree increase in annual average temperature using a panel model estimation with country fixed effects and regional time fixed effects
Sources: Authors' calculations; S&P Global Ratings

Figure 7: Investment, productivity, and agriculture do not recover fully



Response of selected variables to a 1°C annual average temperature rise from 24°C.

Note: The results describe the relationship of the variable shown with average annual temperature using a panel model estimation with country fixed effects and regional time fixed effects. We derive impulse response functions using local projections and controlling for lags and forwards of the temperature
GCF = Gross capital formation
Sources: Authors' calculations; S&P Global Ratings

that they may recover to previous growth rates but not to the baseline trend level. There is no catch-up to previous trend path.

2.3 Hotter temperatures can make downturns worse

We also examine whether temperature change may make severe GDP contractions more likely conditional on climate. Using quantile regressions linking growth to temperature, we find that downside risks to growth (the lower 10th percentile of GDP growth distribution) are more strongly linked to warmer temperature than the central tendency or upside risks (90th percentile) (see tables in the Appendix and Figure 4). This implies that hotter temperatures can make downturns worse, even in economies where the climate is close to what is perceived as the 14°C optimum. As such, the impact of a temperature shock for the 10th growth percentile is more than three times larger than the relationship in the central tendency (the 50th percentile) for 22°C and 24°C economies; the impact on the 90th percentile (that is, when the economy is doing very well in relative terms) appears even slightly positive for temperate climates in comparison and slightly negative as the temperature gets warmer, highlighting a sharp increase in downside risk associated with the overall downward shift in the growth distribution associated with hotter temperatures across countries.

2.4 Yet historical data suggests temperature-driven shocks are relatively milder than other economic shocks

Taken together, the findings in the previous section suggest climate change will make economic convergence more difficult for EMDEs, most of which are located in hotter climates. They also highlight the absence of additional catch-up momentum following a temperature shock. Still, compared with other downturns, such as the global financial crisis, the Asian crisis, or the aftermath of Germany's reunification, our results show that a 1°C increase in temperature for economies averaging 24°C leads to relatively smaller losses (Figure 5). This may result from the external and exogenous nature of extreme weather events, in contrast to the causes of other downturns, which included structural inefficiencies and economic or financial imbalances such as risk buildup or inefficient allocation of resources. That said, the recovery paths are not entirely comparable, since our estimates isolate the effect of a one-time increase in temperature from other drivers of growth, that is if all other factors remain unchanged. Overall, this suggests the impact of temperature increases alone, while having a significant impact on economic activity, especially in hotter economies, may not always be visible in aggregate indicators, especially when other trends come into play.

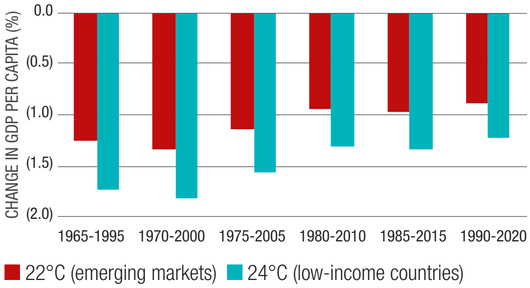
2.5 Agriculture, productivity, and investments experience permanent losses

Looking beyond aggregate growth dynamics to individual sectors sheds light on why the most vulnerable economies (with temperatures averaging 22°C-24°C) could struggle to get closer to richer peers after a temperature shock. Even if there is no permanent loss of growth prospects, the structure of the economy changes if there is a reallocation of resources in response to climate change. Using the same modeling framework (see Appendix), we replaced GDP per capita with other dependent variables (such as value added by sector and GDP components). The results show that, after a rise in temperature, the relative share of agriculture in total output decreases. This seems to come about through lower investment and productivity gains. Mortality also rises, potentially weighing on the long-term labor supply.

On a sectoral basis, agriculture is hardest hit by an increase in temperature, exhibiting a 3.5 percentage point initial loss of output, with output remaining around one point lower seven years later in economies where the temperature averages 24°C. This may be because the crop mix is likely to have benefited less from hotter temperatures, and hotter temperatures depress workers' productivity. Manufacturing output also shrinks, but the impact does not go beyond the year of the shock, while services activity does not appear to be significantly affected (Figure 6). Our results demonstrate that agricultural and manufacturing output is depressed in temperate climates (about 14°C) too, suggesting that those economies also have some way to go to prepare for the threat of climate change.

From a structural growth perspective, we find most of the impact on hotter climate economies (annual temperature averaging 24°C or higher) comes from lower investment, productivity losses, and increased mortality. While infant mortality recovers two years after the temperature shock, investment and productivity are still lower eight years later (Figure 7). By contrast, other components of growth such as average hours worked, capital accumulation, or the rate of depreciation of capital do not seem to be affected. However, since some of those variables are unobservable (for example, the capital depreciation rate), it is unclear whether the data can adequately capture a temperature shock impact or whether that is all captured by the productivity variable.

Figure 8: Adaptation likely explains economies' decreasing sensitivity to temperature shocks

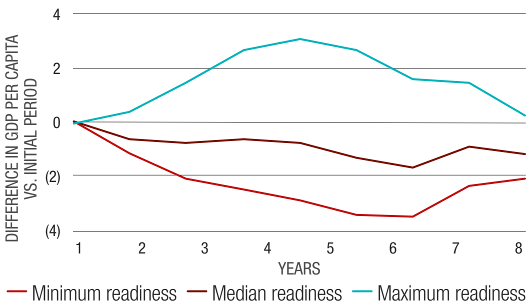


The effect of a 1°C annual average temperature rise on real GDP per capita growth has declined over time.

Note: The results describe the relationship of GDP per capita with temperature using a panel model estimation with country fixed effects and regional time fixed effects

Source: Authors' calculations; S&P Global Ratings

Figure 9: Countries with low readiness display a long-lasting impact on growth

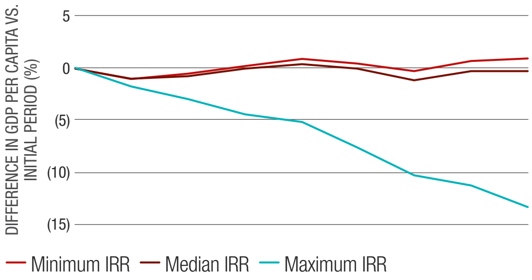


Response over time to a 1°C annual average temperature rise from 24°C

Note: The results describe the relationship of the variable shown with average annual temperature using a panel model estimation with country fixed effects and regional time fixed effects. We derive impulse response functions using local projections and controlling for lags and forwards of the temperature. Readiness as defined by ND-GAIN indicators

Sources: Authors' calculations; S&P Global Ratings

Figure 10: Countries with higher real interest rates display long-lasting effects on growth



Response over time to a 1°C degree annual average temperature rise from 24°C by real interest rate level (IRR)

Note: The results describe the relationship of the variable shown with average annual temperature using a panel model estimation with country fixed effects and regional time fixed effects. We derive impulse response functions using local projections and controlling for lags and forwards of the temperature

IRR = Internal rate of return

Sources: Authors' calculations; S&P Global Ratings

3. IMPROVING READINESS, DEMAND MANAGEMENT, AND ADAPTATION ARE CRITICAL

The results of our analysis provide insight on the economic dynamics at play when a temperature shock occurs. Yet they do not take differences in how countries prepare and respond to climate change into account. In this respect, we find that some adaptation has occurred over the years, with the sensitivity of GDP to a one-off increase in annual average temperature about 30 percent lower in the late 1990s than during 1965-1995 time period (Figure 8). This compares with a 258 percent increase in labor productivity in low- and middle-income countries (based on GDP per capita) between 1991 and 2021. Economies with better readiness to cope with climate change (as defined by the University of Notre Dame's ND-GAIN index) have been able to avoid most of the negative impact related to higher temperatures, while macroeconomic tools, such as lower interest rates, also helped cushion the impact on growth.

3.1 Increased readiness seems to be key to avoiding the negative impact on growth

Countries with the highest readiness (as defined by ND-GAIN indicators those displaying highly flexible product and labor markets, elaborate social safety nets, and stable institutional setups), do not experience a drop in income when temperature rises (Figure 9). Such economies may even experience an initial boost, perhaps due to some adaptation investment in response to the shock. By contrast, countries least ready to cope experience more permanent losses, with GDP per capita still declining up to six years after the temperature shock. Some of the variation in impact is likely linked to the composition of economies, where countries more ready to cope tend to be less dependent on agriculture and more service-oriented economies, like Singapore. However, it also highlights that geography alone is not the main determinant of economic outcome in the face of climate change.

Box 1: What adaptation looks like in practice

Adaptation to climate change can be evident even when readiness is relatively low

Measures of countries' readiness mostly typically reflect high-level drivers of adaptation (that is, the changes required to withstand the impacts from climate change) and resilience (that is, our ability to withstand the impacts from physical climate risks, while incurring minimal damage to society, the economy, and environment), as well as whether a country has the necessary finances and provides an adequate business and institutional environment to make effective use of investments in adaptation.

While our findings suggest that financial capacity and institutional setups play an important role in cushioning economies from losses linked to climate change, they do not tell us much about what countries, companies, and communities have already done to face and manage climate-related risks. Adaptation can also occur where readiness is relatively low, although this often happens with international support for financing and designing technical tools.

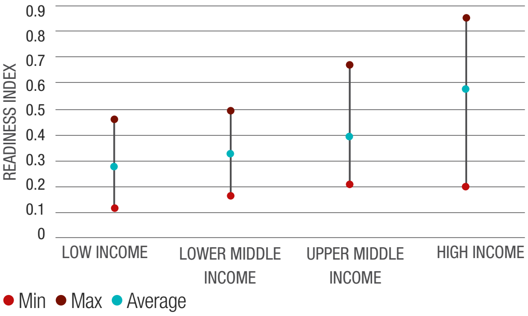
In practice, adaptation measures are multifaceted, reflecting the location- and context-specific nature of vulnerability

However, it is possible to distill adaptation measures into different types, for example:

- **Structural or physical options:** including engineered options such as a sea wall, technology (like an early warning system), or ecosystem-based adaptation, such as the restoration or creation of habitats (like mangroves that can help to reduce the impacts of cyclones, flooding, and coastal erosion).
- **Social:** including improvements to education, information awareness, or behavioral change.
- **Institutional:** including economic incentives, laws or regulations, policies, or programs.

It is also worth noting the significant overlap between adaptation measures and disaster risk reduction (DRR), or disaster risk management (DRM), measures and frameworks – for example, the Sendai Framework for Disaster Risk Reduction (SFDRR) (supported by the European Commission) and the E.U. Strategy on Adaptation to Climate Change, both of which serve to leverage synergies between DRR and climate change adaptation.

Figure 11: Readiness to cope with climate change correlates with higher economic development



Note: A higher score indicates a greater readiness
Sources: Notre Dame Global Adaptation Initiative; authors' calculations; S&P Global Ratings

3.2 Tools to manage demand also influence the direct impact of weather shocks

For example, we identify that when temperature shocks occur during a period of low interest rates, that environment can be of significant help to cushion a one-time climate shock. Economies with the highest real interest rates (of about 1.1 percent in our sample) do not show signs of recovery, even after eight years, in contrast to those with low or the median interest rate (0.01 percent and 0.1 percent respectively; Figure 10). This implies that lower interest rates help economies recover, for example, by providing incentives for investment and lowering the cost of financing for the whole economy. In a broader context, this would suggest that one way less vulnerable countries can help more vulnerable economies cope with climate shocks is by providing concessional finance.[3]

3.3 Adaptation and resilience foster economic development, and vice versa

While we find that high readiness helps countries mitigate the impact of climate shocks, we note that indicators of readiness themselves correlate with economic development given their focus on economic, institutional, and social factors (Figure 11). At the same time, our analysis highlights that climate change is already making it harder for lower-income countries to catch up to more developed nations. This circularity seems to indicate that changes in climate are another barrier to development for EMDEs.

It also implies that economic development and resilience to climate change feed off each other. Viewing adaptation to climate change in this context could thus also support long-term growth prospects for EMDEs. As such, institutional measures to promote adaptation, such as improving education, social safety nets, and product and labor market flexibility, are likely to overlap with economic development goals. Countries may find a third way to escape what seems to be a climate change-economic growth doom loop. Those would likely stem from more granular, readiness measures that work specifically for certain EMDEs, absent strong economic development (for which data is scarce); whereas our cross-country comparison of readiness to cope with climate change focuses on high-level institutional, economic, and social differences.

4. CONCLUSION

The starting point in temperature matters and there is a nonlinear relationship between temperature and growth, these are two important takeaways from this article. By linking economic output (GDP) to countries' annual average temperatures, we document that many advanced economies have more favorable temperature starting points when it comes to climate change. Since lower middle-income and low-income EMDEs are concentrated in areas with much warmer climates, our results suggest that temperature rise would be another dimension holding back this set of countries to achieve durable growth in the long term, which is a precondition for convergence with high-income economies (as implied by neoclassical growth theory), although causal interpretation is difficult. Even though a one-time temperature increase has a temporary impact on economic growth, there is a permanent relative loss of GDP in countries with hotter climates than those with lower average temperatures. Additionally, hotter temperatures can make downturns worse, even in economies where the climate is close to what is perceived as the 14°C optimum. Taken together, our findings suggest climate change will make economic convergence more difficult for EMDEs, most of which are located in hotter climates.

Economies have adapted somewhat to one-off temperature increases over the past decades, with the sensitivity of GDP to temperature shocks decreasing by about 30 percent over the past 20 years. Supportive macro policy responses have also helped economies recover from climate-related shocks, restrictive monetary policy seems to amplify the shock, whereas low real interest rates are associated with little scarring.

[3] https://bit.ly/3KSlpJv

Appendix: Methodology and data

Our model focuses on the short- to medium-term dynamics stemming from a one-time annual temperature shock, rather than the very long-term impact of a chronic increase in temperature. We look at the relationship between temperature and real GDP per capita using a sample of 190 countries. The data underlying this analysis is taken from several sources:

- Climate variables from the Centre for Environmental Data Analysis
- Readiness measures provided by the ND-GAIN database
- Macroeconomic variables from the World Bank's database (GDP per capita, gross capital formation, and infant mortality) and Penn World Tables (sectoral value added, capital, depreciation of capital, productivity, real rates of return, and human capital)
- Data sample from 1965 to 2020; the availability of historical data varies by country.

For our main model, we use a panel regression where GDP per capita growth is a function of:

$$\text{dlog(GDP per capita)}_{i,t} = \beta_1 \times \text{Weather}_{i,t} + \beta_2 \times \text{Weather}_{i,t}^2 + \gamma_1 \times \text{Weather}_{i,t-1} + \gamma_2 \times \text{Weather}_{i,t-1}^2 + \text{dlog(GDP per capita)}_{i,t-1} + \varepsilon_{i,t}$$

Weather variables include average annual temperature (T) and average annual precipitation (P). We also use country (i) and year (t) fixed effects to control for country differences (like macroeconomic conditions, latitude, and economic structure) and time specific shocks. Standard errors are clustered at the country level. Note that we replace GDP per capita with other dependent variables when we investigate the channels of the shock (like sectoral value added and growth components).

For impulse response functions to model the impact over time, we use the Jordá (2005) local projection method. The dependent variable becomes the cumulative growth rate of GDP (or the other dependent variable mentioned) between horizons t-1 and t+h. In the local projection regression, we also add controls for forwards of the weather variables (i.e., temperature and precipitation values in time t to t+h), to ensure that we isolate the effect of the weather shock occurring in time (t). In other words, the model only looks at the short- to medium-term effects of temperature increases on GDP.

For the growth at-risk exercise, we employ quantile regression for panel data on the same specification as above. The following tables show the results for the 10th, 50th, and 90th growth deciles; that is, we create subsamples of the data according to where they sit in the GDP per capita growth distribution (for example, the lowest growth rates would be found in the lowest 10th decile).

Table 1: Basic summary statistics by income*

	NUMBER OF OBSERVATIONS	MEAN	STANDARD DEVIATION	MINIMUM	MAXIMUM
Advanced economies					
High income					
GDP per capita growth	2,931	2.1	4.9	(79.1)	56.9
Temperature	4,026	15.0	9.5	(17.2)	29.5
Emerging markets and developing economies					
Upper middle income					
GDP per capita growth	2,402	2.1	7.6	(105.0)	87.7
Temperature	3,233	19.2	7.8	(6.7)	28.7
Lower middle income					
GDP per capita growth	2,521	1.5	5.2	(46.2)	35.9
Temperature	3,111	21.8	7.2	(2.0)	29.3
Low income					
GDP per capita growth	1,199	0.4	6.7	(64.6)	31.9
Temperature	1,586	24.3	4.6	4.6	29.4

* Data observations for 196 countries in annual average terms from 1960-2020

Table 2: Basic summary statistics by region

	VARIABLES	NUMBER OF OBSERVATIONS	MEAN	STANDARD DEVIATION	MINIMUM	MAXIMUM
East Asia & Pacific	GDP per capita growth	1,411	2.5	5.8	(79.1)	35.9
	Temperature	1,952	22.3	7.3	(2.0)	28.9
Europe & Central Asia	GDP per capita growth	2,067	2.2	5.4	(60.4)	65.3
	Temperature	3,233	8.4	5.5	(17.2)	20.6
Latin America & the Caribbean	GDP per capita growth	1,952	1.5	4.8	(33.8)	35.6
	Temperature	2,196	24.0	3.7	7.9	29.5
Middle East & North Africa	GDP per capita growth	742	1.3	9.6	(105.0)	61.9
	Temperature	1,098	22.3	3.9	15.4	29.3
North America	GDP per capita growth	152	1.8	3.0	(7.1)	11.6
	Temperature	183	8.5	10.8	(7.3)	22.6
South Asia	GDP per capita growth	364	2.6	4.4	(42.6)	22.3
	Temperature	427	20.1	8.0	6.7	28.6
Sub-Saharan Africa	GDP per capita growth	2,365	1.0	6.4	(64.6)	87.7
	Temperature	2,867	24.6	3.3	11.3	29.4

Source: S&P Global Ratings

Table 3: Results for quantile regression for panel data (QRPD)

Number of observations		8,856				
Number of groups		193				
Min observations per group		6				
Max observations per group		59				
For 90th percentile						
GDPPC_GROWTH	COEFFICIENT	STANDARD ERROR	Z	P>Z	95% CONFIDENCE INTERVAL	
temp	(0.07)	0.01	(5.10)	0.00	(0.09)	(0.04)
temp_sq	(0.01)	0.00	(22.12)	0.00	(0.01)	(0.01)
lag_temp	(0.23)	0.01	(18.55)	0.00	(0.26)	(0.21)
lag_temp_sq	0.01	0.00	36.09	0.00	0.01	0.01
lag_gdppc_growth	0.20	0.00	493.09	0.00	0.20	0.20
For 50th percentile						
temp	0.69	0.01	63.95	0.00	0.67	0.71
temp_sq	(0.02)	0.00	(54.39)	0.00	(0.02)	(0.02)
lag_temp	(0.66)	0.01	(57.66)	0.00	(0.68)	(0.63)
lag_temp_sq	0.02	0.00	45.04	0.00	0.02	0.02
lag_gdppc_growth	0.33	0.00	184.02	0.00	0.33	0.34
For 10th percentile						
temp	0.78	0.04	17.66	0.00	0.69	0.86
temp_sq	(0.04)	0.00	(25.06)	0.00	(0.04)	(0.04)
lag_temp	(0.73)	0.04	(16.32)	0.00	(0.82)	(0.64)
lag_temp_sq	0.03	0.00	20.24	0.00	0.03	0.04
lag_gdppc_growth	0.32	0.01	50.86	0.00	0.31	0.34

* Estimates generated using Stata's QRPD, an estimator developed by Powell (2015)

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